Auto Parking System with LiDAR and Reflective Tape for Turtlebot3 Burger Robot

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Abstract. The Turtlebot3 Burger Robot is a standard platform of ROS Robotic cooperation, which is used as a learning media and as a prototype in a delivery robot project. This robot has been modified with the addition of the LiDAR sensor for obstacle avoidance and auto parking, as well as the addition of an indoor GPS component for robot localization and navigation. This prototype will be used as an item shipper from the store to a certain product line in a company. In this research, autonomous navigation is made so that the robot can move according to the robot's point and mission by utilizing Indoor GPS. So that the robot can move properly without interference from the obstacle, an obstacle avoidance system is made by utilizing the LiDAR sensor, which will detect the obstacle and then make a decision to avoid the obstacle. After the robot completes its mission, the robot can return to the home base position autonomously using reflective tape as a reference. This research has found one way how the mobile robot can find out and move to its home position by using reflective tape as a reference, with the method and specifications of the sensor used, the farthest distance that can be detected is 1.6 meters.

Keywords: Turtlebot3, autonomous, Indoor GPS, obstacle, LiDAR, auto parking, reflective tape.

1 Introduction

As time goes by, the company's need for production capacity has increased. Products must be produced in sufficient quantities over a certain period of time. This requires the company team to work faster with optimal results. The distribution of goods is an important part of making a product. However, this will take more time and energy if done personally and repeatedly. Therefore, an automatic device is needed to distribute goods, such as a delivery robot.[8], [9].

To create a delivery robot project that suitable with the company's problems, a learning media and prototype are needed that can run autonomously with a good navigation system. Researcher R Sridhar offers a solution using LED and LDR as sensors to detect the color of the lines installed on the floor as a reference for movement. The robot movement route is

ICAE 2022, October 05, Batam, Indonesia

DOI 10.4108/eai.5-10-2022.2327482

distinguished by color [1]. Most of these systems have been widely used in Indonesia. However, it has several disadvantages, such as having the potential to damage the surrounding environment. The prototype must be able to run according to field conditions in the company. In this study, the author uses the Turtlebot3 Burger as a learning medium for the manufacture of a delivery robot system.

The Turtlebot3 robot offers solutions to solving the Company's problems. Small, affordable, programmable, ROS-based mobile robots used in education, research, hobbies, and product prototyping [2].

One of the systems that are quite important in the mobile robot is the auto docking system which is used when the battery is low, and the robot will return to the power station to recharge the battery [3]. So that the robot to complete its mission point autonomously, the robot needs a battery as its power supply. Based on the company's needs, the robot must be able to operate for a long time. This requires the robot to always have enough power. Therefore, the robot is expected to be able to find its own charging location both before and after operating.

The robot can move to charging location autonomously, which is represented as a home position. The LiDAR function, apart from being able to detect objects, can also read intensity. The intensity reading becomes a reference in finding the home position in the auto parking system. This research is expected to be able to contribute in the world of robotics, especially for industries where robots are needed so that with this research, the robot can return to its home to perform automatic charging [6].

From the various problems that have been mentioned, the expected results with all research carried out by robots can carry out missions with strategies that have been made based on the needs of the Company in the field that have been made.

2 Literature Review

In the Turtlebot3 Burger robot, the robot is required to search and move to the home position. Therefore we need a method that can support research. Research on the Auto Parking section uses an Inertial Measurement Unit (IMU) and Light Detection and Ranging (LiDAR) as sensors. The IMU sensor used in this study is the MPU9250, which has been embedded in the OpenCR board, while for the LiDAR sensor, this study uses LDS-01.

2.1 Robot Operating System (ROS)

Robot Operating System, also known as ROS, is an open-source set of software libraries and tools that help to build robot applications [10].In this research ROS used as a communication protocol between microcontroller OpenCR and onboard computer RaspberryPi with cable, and RaspberryPi to PC with a router. All sensor reading data is published to ROS topic, also some services already available provided by Turtlebot3 Robot [2].

2.1 Light Intensity

Luminous intensity is a basic physical quantity to measure the power emitted by a light source in a certain direction per unit angle. The intensity emitted by a field is different, several factors that influence it are the distance and its reflectivity ability. The intensity of light is directly proportional to its reflectivity and inversely proportional to its distance. The amount of light intensity will be used in the auto parking system as input for the lidar sensor to determine the parking space.

LM (Lumens) is a unit of measurement that represents the total amount of light emitted from a light source, so it can be concluded that the higher the Lumens, the brighter the light.

Lux is a unit of measurement of light where an area is also taken into account. 1 lux is equal to 1 Lumens/m2, or it can be concluded that the intensity of light in a certain area. This allows us to measure the total "amount" of visible light present on a surface.

2.2 Reflective Tape

Reflective Tape is a flexible reflective material primarily used to increase the visibility of traffic signs at night, high-visibility clothing, and other items so that they can be seen safely and effectively in the light of approaching drivers' headlights. They are also used as an ingredient to increase the scanning range of barcodes in factory settings. Reflective Tape consists of retroreflective glass beads, microprisms, or encapsulated lenses that are sealed on a cloth or plastic substrate. Many different colors and degrees of reflection intensity are provided by many manufacturers for various applications. As with retroreflectors, tape will shine brightly when there is a small angle between the observer's eye and the light source directed at the tape, but appear unreflective when viewed from other directions[7].

Fig. 1. Reflective tape.

2.3 Light Intensity Detection with LiDAR Sensor

This robot utilizes a lidar sensor to read the light intensity, and the lidar sensor will read the light intensity and distance at every angle (360 degrees). Then the robot will look at which angle has a high light intensity because it will indicate that there is a reflective tape (parking lot).

The way LIDAR Tof works is by emitting a laser beam towards the object, and then the reflection of the light will be received by the receiver. The travel time from the time the light is emitted until it is received back will be the divisor of the speed of light. The comparison between the speed of light and time will produce distance data [4]. LiDAR used is 360 Laser Distance Sensor LDS-01.

Fig. 2. Laser Distance Sensor LDS-01.

Table 1. LiDAR general specifications.

Items	Specifications
Operating supply voltage	5V DC ±5%
Light Source	Semiconductor Laser Diode (λ=785nm)
Laser safety	IEC60825-1 Class 1
Current consumption	400mA or less (Rush current 1A)
Detection distance	120mm – 3500mm
Interface	3.3V USART (230400 bps) 42 bytes per 6 degrees, Full Duplex Option
Ambient Light Resistance	10000 lux or less
Sampling Rate	1.8 kHz
Dimensions	69.5 (W) x 95.5 (D) x 39,5 (H) mm
Mass	Under 125g

Table 2. LiDAR measurement performance specifications.

Items	Specifications
Distance Range	120 – 3500mm
Distance Accuracy (120mm – 499mm)	± 15mm
Distance Accuracy (500mm – 3500mm)	± 5.0%
Distance Precision (120mm – 499mm)	± 10mm
Distance Precision (500mm – 3500mm)	± 3.5%
Scan Rate	300 ± 10 rpm
Angular Range	360°
Angular Resolution	1°

The method used is similar to return to home feature on the Mi Robot Vacum-Mop Essential, Some reflective tape is arranged in a pattern and placed inside the charging dock.

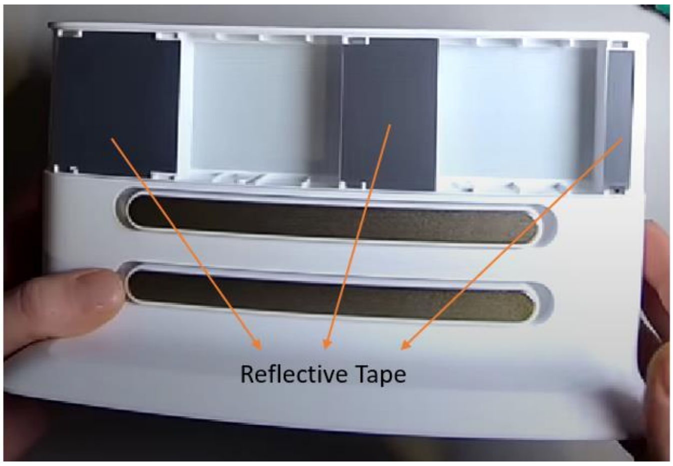


Fig. 3. Mi Robot Vacum Mop Essential charging dock.

2.4 Auto Parking System

The current parking system requires a touch of automation so that it can be used more optimally and efficiently. Technology that is growing rapidly can help humans work in the parking sector and will greatly save time. For this reason, a system was created that can assist human work in the parking system [5]. Automatic parking is an autonomous car maneuvering system that moves vehicles from the traffic lane to the parking lot to perform parallel, perpendicular, or corner parking. The automatic parking system aims to increase the comfort and safety of driving in a confined environment where a lot of attention and experience are required to drive a car.

In this study, after the robot knows its home position, the robot will move backward until it enters the home. Behind the robot, a limit switch is also installed which will give an indicator to the robot if the robot has entered the home and must stop.

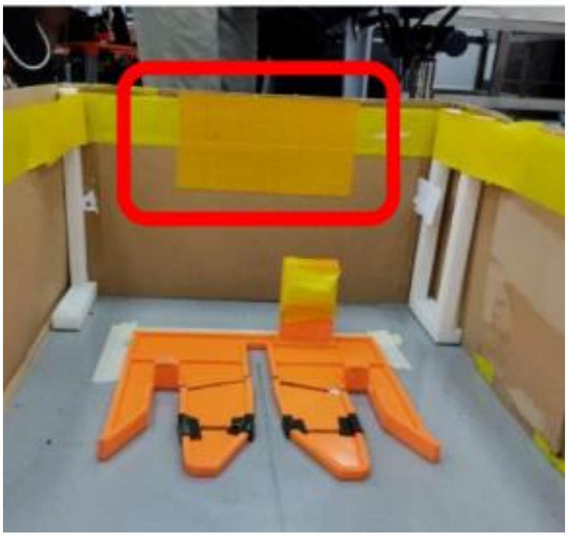


Fig. 4. Home position.

3 Method

Based on the company request for a delivery robot project through the Turtlebot3 burger robot prototype, the robot is asked to return Home (Docking) after completing the mission.

The following equation is used to determine whether the area at that angle has a high light intensity or not.

$$intensity = \frac{lux^2 \; x \, range}{100.000}$$

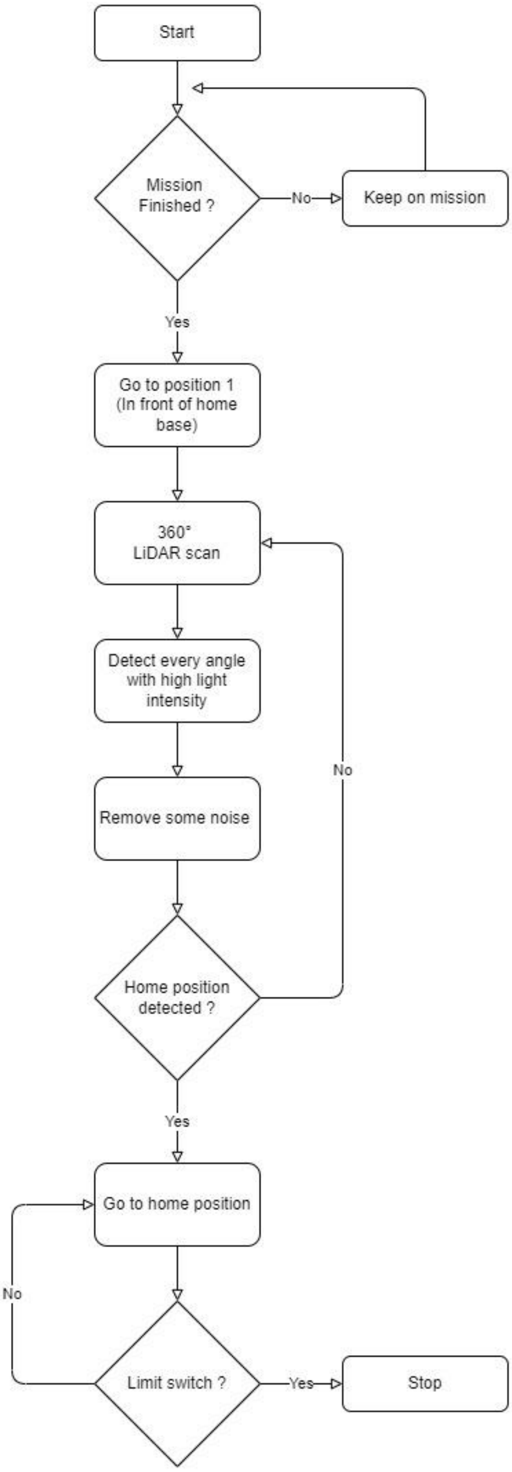
$$intensity \; tresshold = 150 \quad (1)$$

The lux and range values come from the LiDAR , and I need to set the intensity threshold, If the intensity is more than 150, then the area is considered to have high light intensity. When lidar has detected 360° this will be the visualization, red circles indicate areas of high intensity, while black circles indicate low intensity.

Below is Pseudocode how to find the home position

```
program to find a home position;
begin
array intensities[360],ranges[360],intensity[360]
integer intensity_tresshold = 150
boolean limit_switch
```

```
while limit_switch = 0
          read intensities, ranges
          intensity =  intensities ** 2 * ranges / 100000
          if intensity > intensity_tresshold
             intensity = 1
          else
             intensity = 0
          display (every angle with intensity = 1)
          remove some noise
          find the pattern
          calculate robot position angle to the pattern
          go to home position
stop the robot
end
```



Start
Mission
Finished ?
No
Keep on mission
Yes
Go to position 1
(In front of home
base)
360°
LiDAR scan
Detect every angle
with high light
intensity
Remove some noise
No
Home position
detected ?
Yes
Go to home position
No
Limit switch ?
Yes
Stop

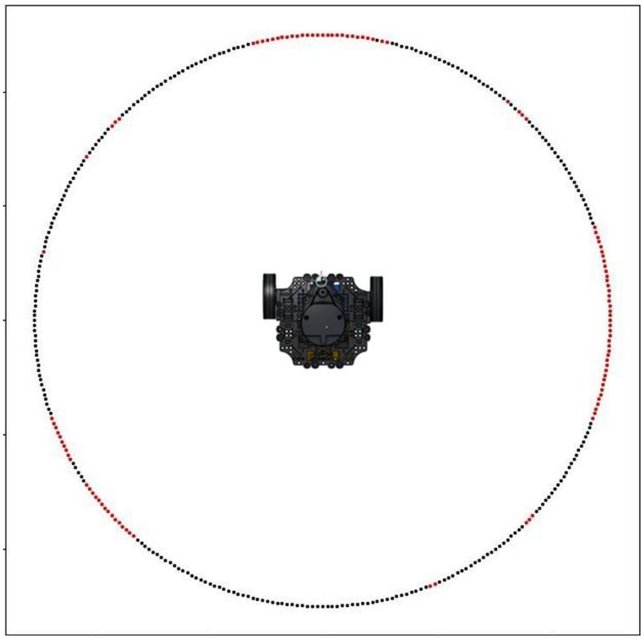


Fig. 5. LiDAR scan results.

this is a visualization of 360-degree lidar sensor readings, red dots indicate high-intensity areas, and vice versa black dots indicate low-intensity areas

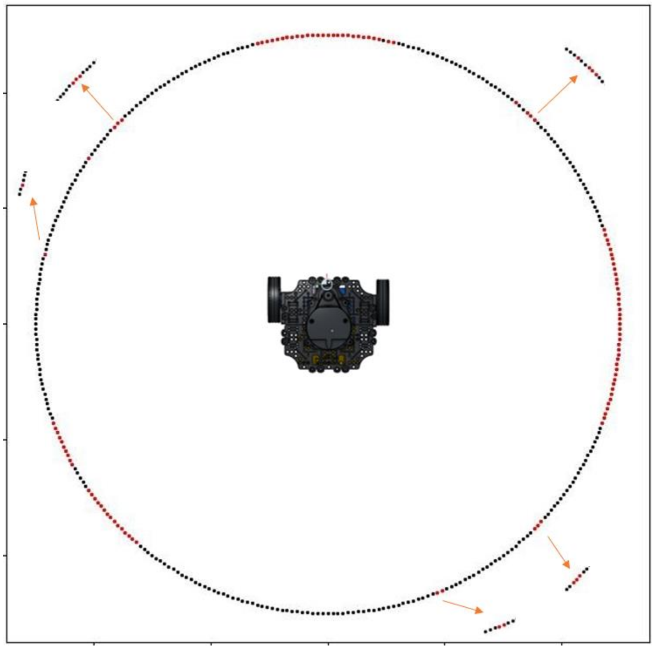


Fig. 6. Small obstacles.

Because the sensor readings are in the real environment, there is some noise that can be obtained, for example, aluminum, if placed at a close enough distance then it can be read as a reflective material, so we need to filter the little noise before go to the next filter. After small obstacles are removed, it is still possible to have some areas of high intensity, so the home must have a unique pattern. In this study, I used a pattern like a picture below.

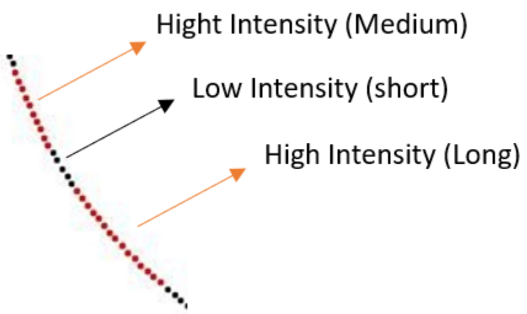


Fig. 7. Classification of intensity data.

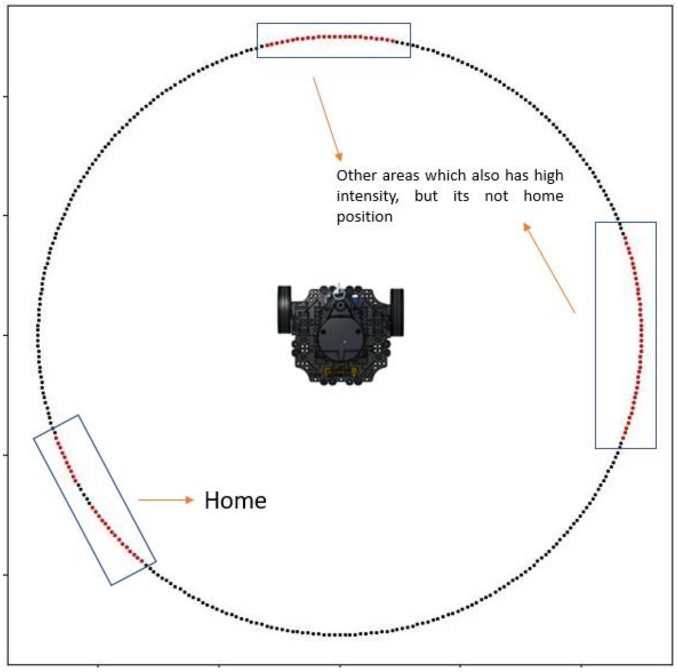


Fig. 8. Data visualization after small obstacles are removed.

Although some noise has been removed, but there is still a possibility that there are areas with high intensity, for example in the industry employee clothes usually have reflective tape behind the shoulder or somewhere else. But because we already set a unique pattern for home the robot will know the exact home position . After the pattern is found, the robot can calculate the angle between home with the orientation of the robot.

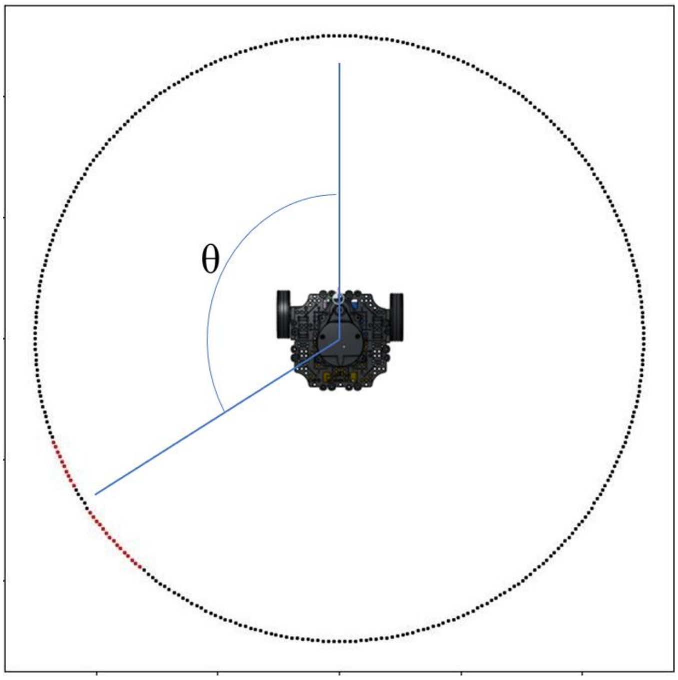


Fig. 9. Robot determines its position.

4 Testing and Analysis

4.1 LiDAR Sensor Test

This test is carried out to find out how far the reflective tape can be read by the sensor, this test is tested at 1 angle only because the data reading at each angle is similar.

Table 3. Testing LiDAR sensor to the reflective tape.

Range (mm)	Lux	Intensities
50	21640	234
100	15224	231
150	12396	230
200	10671	227
250	9452	223
600	6012	216
700	5490	210
800	5108	208

900	4740	202
1000	4389	192
1200	3824	175
1400	3441	164
1600	3132	156
1800	2821	143
2000	2549	129

From the test table above, because i set the intensity threshold to 150 so, it can be concluded that the home position can be detected as far as 1600mm or 1.6m from the robot.

The following is a data visualization from TABLE 3. The X axis here represents the Lux and the Y axis represents the distance.

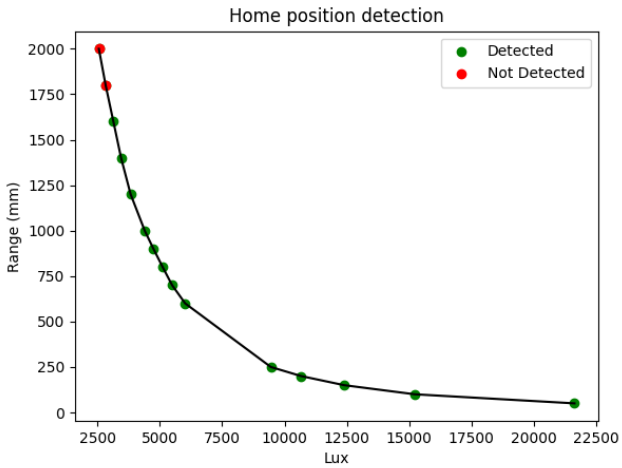


Fig. 10. Visualization of LiDAR sensor to the reflective tape.

4.2 Robot Test to Parking Station

This test was conducted to determine the percentage of success of the robot in entering the parking station. Robot testing on the parking station is very necessary because this output will determine whether the robot can enter the parking station correctly. This test is carried out at a constant speed of 0.14 m/s and a scan rate of 300 ± 10 rpm.

Table 4. Robot test to the parking station.

Range (mm)	Angle	Parking Station
50	30°	✓
80	30°	✓
100	30°	✓
200	30°	×
50	45°	✓
80	45°	✓
100	45°	✓

200	45°	✓
50	90°	✓
80	90°	✓
100	90°	✓
200	90°	✓
50	135°	✓
80	135°	✓
100	135°	✓
200	135°	✓
50	150°	✓
80	150°	✓
100	150°	✓
200	150°	×

5 Conclusion

Based on the results of research on the Auto Parking System Using LiDAR and Reflective Tape on the Turtlebot3 Burger robot, the Robot can already find its home position and move to its home position. This method also can filter the noise, so the home position detection is correct. To make this system better, the docking can bse modified so that there is no slippage on the tires. Which sometimes makes the robot stop moving.

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